



Logistics User Guide

JN-UG-3069

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About this Manual

This User Guide accompanies the Jennic *Logistics (JN-RD-6014)* Reference Design.

The Reference Design provides an example application that uses a sleeping beacon network, Jennic's patent pending sleeping beacon technology, to control and manage a sensor networks monitoring goods in transit. The design could easily be adapted for other small or large sensor network applications that require a low power synchronised total sleeping network.

The Reference Design includes all files to run the logistics demonstration on the boards of a Jennic JN5139 and JN5148 Evaluation Kit.

This manual describes use of the supplied binary files to implement the logistics demonstration system. You are advised to study the first three chapters of this manual before attempting to use the demonstration system.

Organisation

This manual consists of 4 chapters, as follows:

- [Chapter 1](#) Introduces the demonstration.
- [Chapter 2](#) Installation of the demonstration software.
- [Chapter 3](#) Getting Started
- [Chapter 4](#) Advanced Features

Conventions

Files, folders, functions and parameter types are represented in **bold** type.

Function parameters are represented in *italics* type.

Code fragments are represented in the `Courier` typeface.

Acronyms and Abbreviations

API Application Programming Interface

Related Documents

- [R1] Logistics Reference Manual [JN-RM-2048]
- [R2] Sleeping Beacon Reference Manual [JN-RM-2050]
- [R3] 802.15.4 Toolbox Reference Manual [JN-RM-2051]

Feedback Address

If you wish to comment on this manual, or any other Jennic user documentation, please provide your feedback by writing to us (quoting the manual reference number and version) at the following postal address or e-mail address:

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1 Introduction

This chapter introduces the Jennic *Logistics (JN-RD-6014)* Reference Design.

1.1 Available Packages

The *Logistics (JN-RD-6014)* Reference Design contains all the necessary files to run the demonstration on the boards of a Jennic JN51xx Evaluation Kit and is available in two packages.

- **Demonstrator (JN-RD-6014-Logistics-Evaluation.zip)**, including:
 - Logistics demonstration software as a set of pre-compiled binaries (to be loaded into the evaluation kit boards)
 - PC application software to communicate with the JN51xx software.
 - Logistics User Guide (this manual)
 - Software License Agreement (SLA)
 - Questionnaire in the form of a spreadsheet
- **Developer (JN-RD-6014-Logistics-Developer.zip)**, including:
 - Full development environment for Logistics supplied as a drop-in application for the Jennic SDK - includes project files and source code for all the builds in the demonstrator package
 - Logistics Reference Manual (JN-RM-2048)
 - Sleeping Beacon Reference Manual (JN-RM-2050)
 - 802.15.4 Toolbox Reference Manual (JN-RM-2051)

To run the demonstration, it will first be necessary to programme the supplied demonstration binaries into the Flash memory of the evaluation kit boards - this is described in Chapter 2.



Note: If you have the Evaluation Package, have run the demonstration and now need the Developer package, fill in the questionnaire and complete the Software License Agreement from the Demonstrator pack and submit to Jennic.

1.2 Demonstration Overview

The software provided in the Logistics Reference Design demonstrates the use of 802.15.4 wireless technology to allow security and environment monitoring of cargo while in transit. The reference design provides a software framework which handles the network synchronisation and timings. This allows the application designer to concentrate on the end application, tailoring the software to suit the users' needs,

Jennic's advanced architecture allows for power management of the system controller, enabling the system to still monitor the wireless network while running off a backup battery, when the trailer is unhooked from the tractor.

The use of the Jennic microcontroller to manage the GSM/GPRS and GPS modules, only activating them when it is necessary to service an alarm, allows the system to function for extended periods while removed from the main power source.

Sensors are positioned around the vehicle transporting the cargo to monitor the environment and the access to the cargo. Jennic's sleeping beacon auto tuning/optimisation features enables the sensors to have a multi-year battery

The controller (consisting of the 802.15.4 Coordinator, GPS module and GPRS module) is also attached to the trailer so that the cargo can be monitored when the trailer is un-hooked from the tractor.

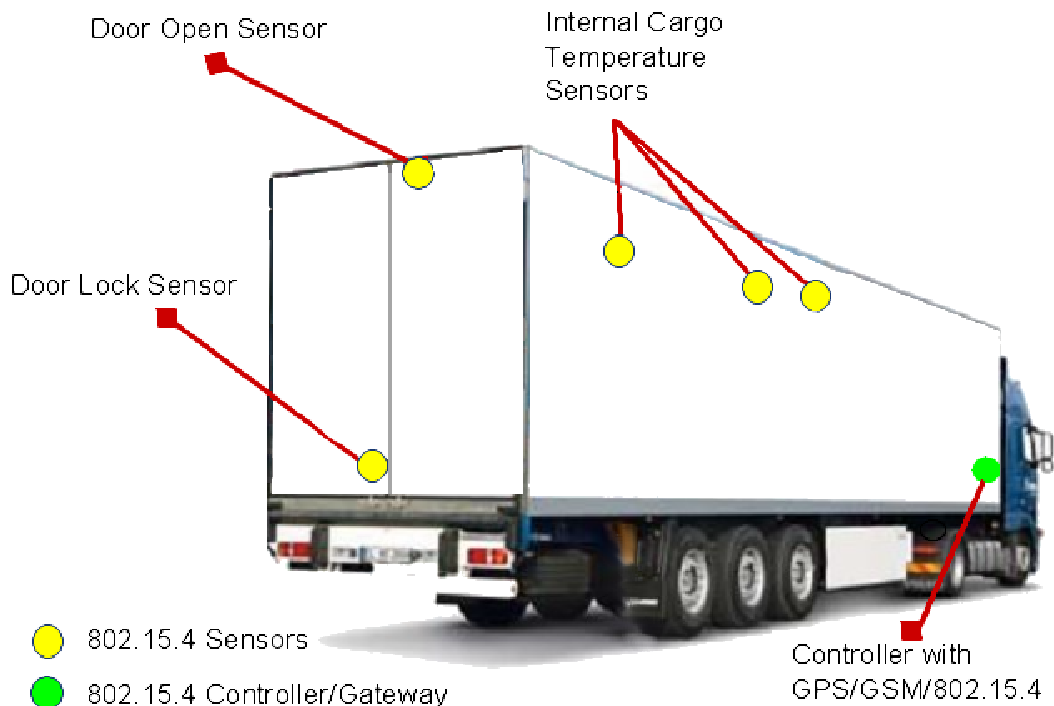


Figure 1 Example System

Each sensor periodically reports their sensor data and battery voltage to the coordinator. On receipt of the sensor data the coordinator can report, if necessary, the data to the back off system via the GPRS link.

All the wireless sensors will be battery powered and it is intended that the coordinator will also be battery powered when un-hooked from the tractor.

As described above, a real life, fully functioning system comprises of the following:

- 1 or more sensors
- 802.15.4 Coordinator
- GPS module
- GSM/GPRS modem.

Although the diagram above shows multiple sensor types, a GPS module and a GPRS modem; due to the multitude of hardware possibilities only one sensor type is demonstrated, a temperature sensor, and the backoffice communication is simulated by a serial link between the coordinator and PC application. This allows the user to add other sensor types and communication mechanisms as required to suit the end application.

The features of demonstration include:

- Ability for the coordinator to automatically sleep during idle periods
- The Coordinator performs frequency agility to ensure the current RF channel is free from interference. If interference is detected then it will manage the process of moving the whole network, seamlessly, to a new channel.
- End devices sleep automatically when idle, and automatically optimise the sleep times for optimal battery life.
- End devices report supply voltage and temperature to the coordinator
- Configurable number of end devices only limited by RAM space
- A PC application, connected by RS232, to demonstrate backoffice communication

1.3 Network Configuration

The network runs on boards of the JN51xx evaluation kit. The Controller board (with LCD screen) acts as the network Co-ordinator and gateway, with a serial command interface to a PC running the logistics application.

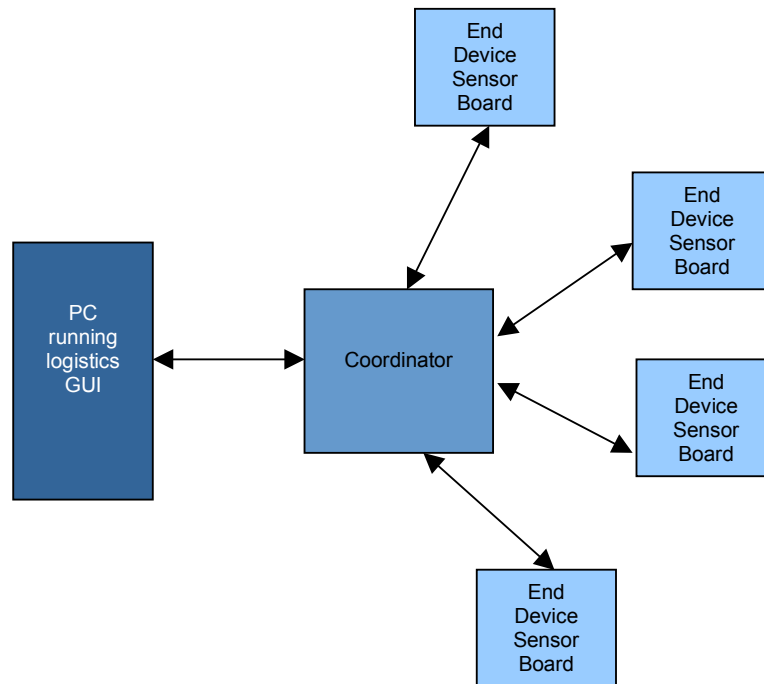


Figure 4: Demonstration Network

The demonstration system is an 802.15.4, beacon enabled star network, consisting of a coordinator and one or more end devices. The use of a beacon-enabled network allows the coordinator and end devices to sleep in-between beacons.

A beacon-enabled network requires that end devices regularly receive a beacon packet transmitted by a Personal Area Network (PAN) coordinator. Between such packets, the end device enters a low power sleep mode, but maintains a sleep timer to wake the CPU in sufficient time to receive the next beacon packet. To guarantee receiving the beacon, the end device must wake early in order to compensate for any inaccuracy between the end device and coordinator clocks.

The Sleeping Beacon software manages the wake-up time to ensure the receiver is enabled as close as possible to the start of the beacon packet, reducing receiver current.

For detailed information on sleeping beacon network please see ref[2]

Since the system is a star network, all end devices must be in radio range of the coordinator and can only talk to the coordinator.

The use of a beacon enabled network allows all devices to be synchronised. As such, all end devices (sensors) will know when the coordinators radio is active. This allows the coordinator to sleep during inactive periods to conserve battery power.

1.3.1 Co-ordinator Role

- At start-up the coordinator selects a random PAN ID and then performs an active scan to determine if any other networks are using this PAN ID.
- If the same PAN ID is found, the process is repeated to find a free PAN ID. After the PAN ID selection an energy scan is performed to determine best channel.
- The Coordinator initiates a beaconing 802.15.4 star network with the selected PAN ID and channel. Beacons are transmitted every 3.932 seconds, of which 122.88 mS is assigned for network communications and 3.809 seconds idle time. (see ref[2] for more information)
- After the super frame an energy scan is performed across all channels then the coordinator will sleep until the next beacon needs to be transmitted.
- The serial interface to the PC is serviced while the coordinator is awake, and if a connect message is received from the PC the coordinator will remain awake until the PC disconnects.
- A list of all end devices associated with the coordinator is maintained. Network context, and associated end devices are stored in flash and therefore maintained over a device reset.

1.3.2 Sensor (End Device) Role

When a sensor first powers up it performs the following procedure:

- Seed Random number generator with MAC address.
- Sleep for a random period between 1 and 6 seconds.
- Perform energy scan over all channels.
- Seed Random number generator with result from the energy scan.
- Sleep for a random period between 1 and 60 seconds
- Synchronise and Associate with the coordinator.
- Save Network context in flash.

The sequence above allows the sensor associations to be distributed over a 1 minute transmission cycle as allowing all sensors to associate at the same time would cause network congestion, and have a detrimental effect on battery life. After association, the sensors perform the following procedure:

- Wake every 15th Beacon transmitted by the coordinator.
- After receipt of the beacon, its sensor data and network statistics will be transmitted back to the coordinator.
- Sensors auto tune their sleep period to ensure the optimum wake times.

- The sleep period is automatically handled by the MAC sleeping beacon functionality. The application can choose not to sleep or delay the sleep for a period.
- Using an external 32KHz oscillator the early receive window is automatically tuned to approximately 3mS.



If the coordinator did not have to switch between sleeping and non-sleeping states (i.e. always on or always in sleeping beacon mode) the early receive window can be tuned to approximately 300uS.

1.4 Platform Compatibility

The software provided with this Reference Design has been tested with the following Jennic kits and SDK versions:

Product Types	Part Numbers	Version	Supported Networking Protocols
Evaluation Kit	JN5139-EK000	-	
	JN5139-EK010	-	
	JN5148-EK010	-	
SDK Libraries	JN-SW-4030	1.5	IEEE 802.15.4
	JN-SW-4040	1.1	IEEE 802.15.4
SDK Toolchain	JN-SW-4031	1.1	-
	JN-SW-4041	1.0	-

2 Installation

This chapter provides instructions for installing the demonstration software.

2.1 Installing the Demonstration on a PC

This Reference Design contains the logistics demonstration software in a ZIP package:

JN-RD-6014-Logistics-Evaluation.zip

Unzip the package and copy the **JN-RD-6014-Logistics- Evaluation** folder to:

- **C:\Jennic\cygwin\Jennic\SDK\Application (for JN5139)**

- **C:\Jennic\Application (for JN5148)**

or your equivalent folder.

2.2 Programming the Boards

You must now program the evaluation kit boards with the appropriate demonstration binaries provided in the folders:

SDK\Application\JN-RD-6014-Logistics-Demonstrator\Binaries\JN5139 or
SDK\Application\JN-RD-6014-Logistics-Demonstrator\Binaries\JN5148

The binary files must be loaded into Flash memory on the boards using the Jennic JN51xx Flash Programmer. This tool is provided in the *Jennic SDK Toolchain (JN-SW-4031)* and its use is described in the *JN51xx Flash Programmer User Guide (JN-UG-3007)*. You will use the USB-to-serial cable provided in the evaluation kit to connect the PC to each board in turn (see the steps below) - during this connection, you may be prompted to install the driver for the cable onto your PC (this connection and installation are covered in the *JN51xx Flash Programmer User Guide*).

The binaries should be loaded into the boards as follows:

Step 1 Program the Co-ordinator

Program the Controller board (with LCD screen) as the Co-ordinator by loading the file **coordinator_ext.bin**.

Step 2 Program the End Devices

Program the Sensor boards as End devices (which will act as sensors) by loading the appropriate binary file.

Two binary files are provided for the sensor: **enddevice.bin** for use when NO external 32KHz oscillator is fitted and **enddevice_ext.bin** for use when an external 32KHz is connected to DIO9.



The **enddevice.bin** should only be used for demonstration as the internal 32KHz RC Oscillator is low cost and low power so does not have the required accuracy for the sleeping beacon applications.

Nodes using the internal oscillator will have a high number of missed beacons and have an extra 100mS receive time on each beacon receive, resulting in shorter battery life.

3 Getting Started

The back office demonstration software consists of a PC application which connects via serial port to UART0 of coordinator. It performs the following functions:

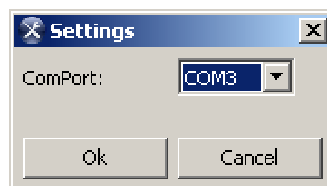
- Once connected will poll the coordinator for device information every 5 seconds.
- While connected the coordinator does not sleep so PC can communicate.
- Collects the last received sensor reading for each associated device.
- Displays frequency agility information.
- Allows user to reset network and force re-association of all devices.
- Allows user to delete devices from the coordinator associated tables.

Set up and configure the serial communications link between the PC and the coordinator, as follows:

- Step 1** Connect a PC USB port to the UART0 connector on the Controller board using the USB-to-serial cable provided in the evaluation kit, making sure you connect the black wire of the cable to Pin 1 of the on-board serial connector.
- Step 2** Power-on the Controller board and wait for LED D1 on the board to flash slowly. This can take up to a minute to start flashing.
- Step 3** Execute the logistics application (JN_RD_6014_Logistics.exe).
- Step 4** Configure serial COM port by selecting settings button.

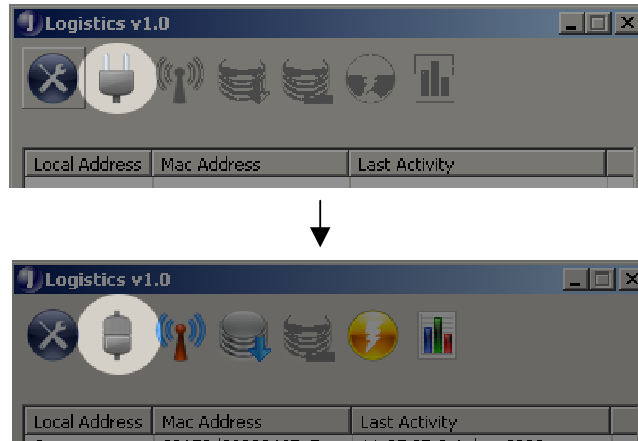


- Step 5** Select desired COM port then click on OK.



Comport will now be saved and re-used every time the application is started.

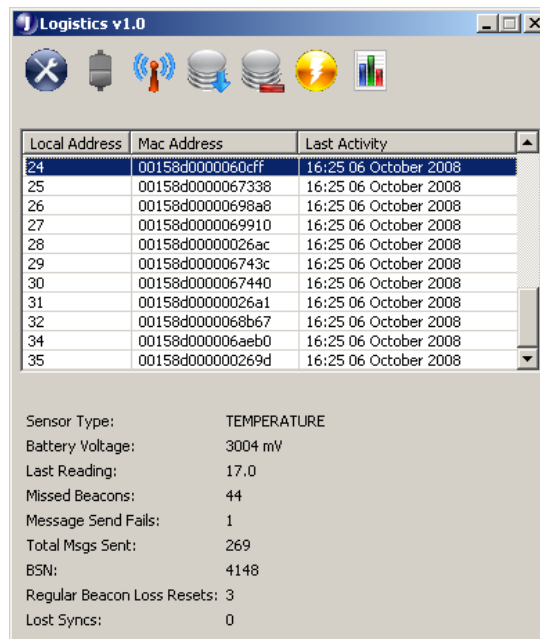
- Step 6** Click connect to connect to the coordinator, it may take up to 4 seconds to connect as the system must wait for the coordinator to wake.



Once connected the PC software will automatically poll the coordinator for data. The data will be listed on the main screen.

- Step 7** Switch on the Sensor nodes and wait approximately 2 minutes for each device to report their first sensor reading.

- Step 8** Clicking on a device line will show detailed information about the device:



For each sensor, the following information can be seen.

- Sensor type: Each sensor reports its type, for the demonstration there are only temperature sensors.
- Battery voltage: The sensors supply voltage in mV
- Last Reading: Last sensor reading. For the temperature sensor this is in °C.
- Note: the reading is from the uncalibrated internal temperature sensor and as such a variation of ±10 °C will be seen between sensors.
- Missed Beacons: The number of beacons the sensor has missed.
- Message Send Fails: The number of messages that have failed to be transmitted to the coordinator.
- Total messages sent: Total messages the sensor has tried to send.
- Messages that were received = Total messages sent - Message Send Fails
- BSN: The Beacon Sequence Number when the packet was received
- Regular Beacon Loss Resets: Number of sensor resets due to regularly missing beacons.
- Lost Syncs: The number of times the sensor lost synchronisation, I.E. missed 3 consecutive beacons.

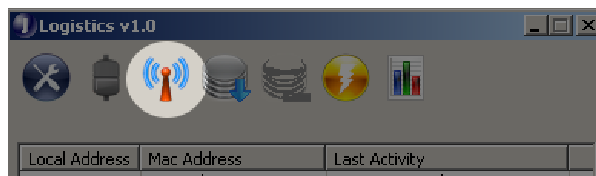
4 Advanced Features

4.1 Frequency Agility

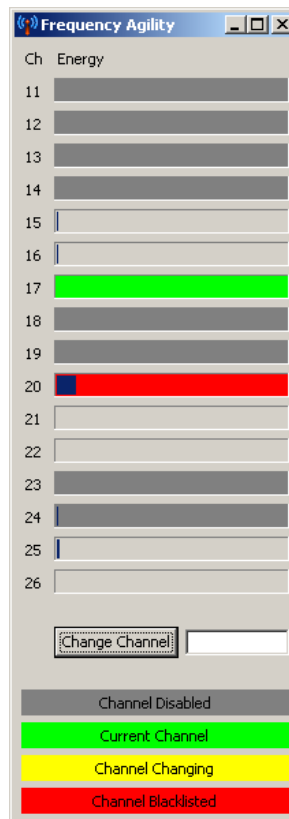
The coordinator performs an energy scan of all channels after the beacon super frame has ended. When a channel energy level exceeds a pre-determined value it will be “black listed”. If the current channel exceeds a pre-determined value a channel change will be initiated.

The network channel change is synchronised to a particular beacon so that all sensors can determine when the change happens. Sensor sleep for 1 minute it will take 2 minutes for the change to take effect.

To view the frequency agility information click on the radio aerial tool button.



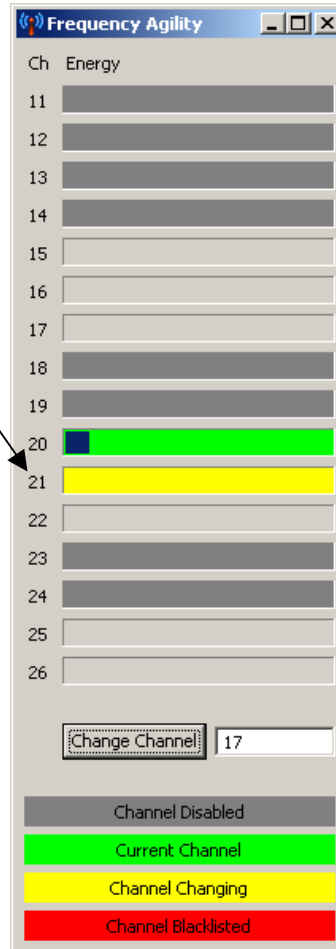
It provides “Site Survey” style user interface to show current status of all channels within the 802.15.4 2.4GHz spectrum.



The frequency agility window is updated every 2 seconds while connected to the coordinator. It shows current detected energy levels for all channels and displays black-listed channels.

When the current channel is deemed busy, a channel change will be broadcast on the Notification Control Channel (NCC). The NCC command indicates to sensors the number of beacons before the channel change will happen.

The FA information display shows the next channel that the system is going to hop to:



4.2 Upload Sensor Information



The PC application automatically updates the sensor information every 5 seconds. Clicking on the upload sensor information button will request an update immediately.

4.3 Remove Device

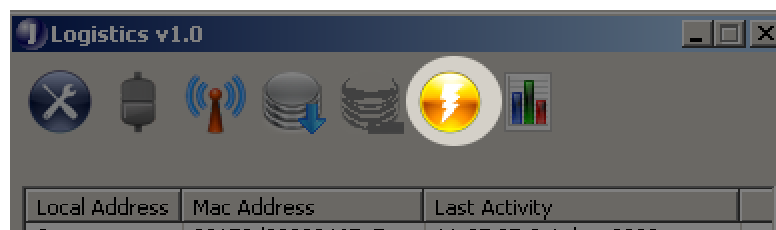


The delete sensor button will send a command to the coordinator to remove the device from the coordinators tables. After the sensor has been deleted, all packets will be ignored from the sensor.

To re-enable the sensor it will have to re-join the network. This can be done by the following methods:

- 1- Reset the sensor while pressing SW1 and SW2 to reset it's network context
- 2- Issue a whole network reset by pressing the Network Reset Button on the PC application.

4.4 Network Reset

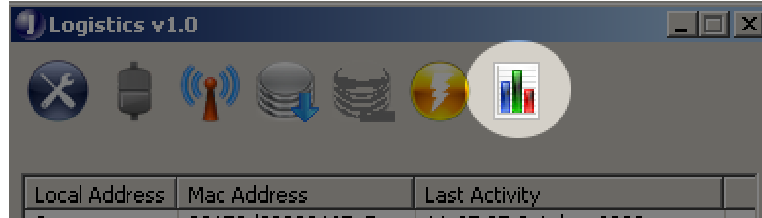


The network reset button commands the coordinator to issue a network reset to all devices. On receipt of the command, the end devices will invalidate the network context in flash and then reset.

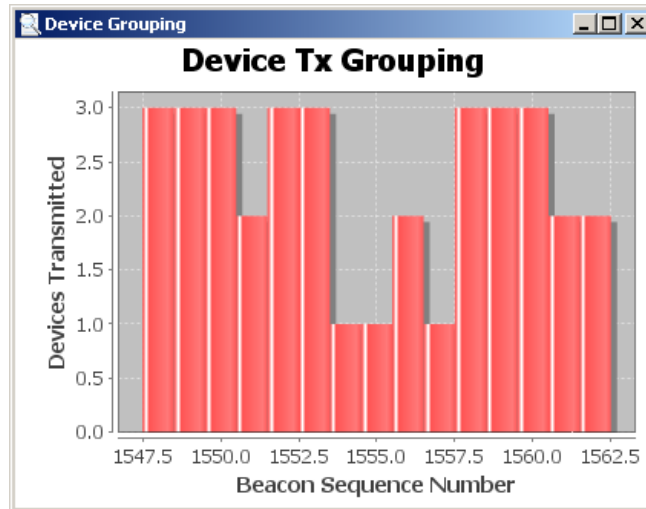
After the reset the end device will associate after the normal delay procedure (approximately two minutes).

4.5 Sensor Grouping

When a sensor wakes and receives a beacon it will transmit its sensor data back to the coordinator. To optimise battery usage devices should be spread out among different beacons so to minimise time spent for CCA and message retries.



The group button in PC software allows visualisation of transmission grouping.



The graph above is an example of a 35 node network. Node transmissions are spread over 1 minute, I.E. 15 beacons. This shows good network balancing.

Appendix

A Board modification



The sleeping beacon functionality requires an accurate 32kHz crystal oscillator for both the coordinator and end device, to allow maximum battery efficiency. A recommended oscillator is the Epson toyocom SG-3030 or SG-3040. The oscillator needs to be connected to DIO9, Pin 10 on J4 of the sensor boards

When using an external 32KHz clock source with the standard Jennic evaluation sensor boards remove R5 and R6 to optimise current consumption during sleep.

This should be done for the coordinator and end devices.

Revision History

Version	Date	Description
1.0	22-Oct-2009	First release
1.1	10-Dec-2009	Minor updates for JN5148

Important Notice

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